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The ACTS Mobile Terminal Reflector Antenna System

Arthur C. Densmore, Antenna Systems Engineer
Vahraz Jamnejad, Antenna Engineer
T. K. Wu, Antenna Engineer
Kenneth Woo, Spacecraft Antenna Research Group Supervisor
Jet Propulsion Laboratory

JPL has developed several mechanically steered L-band antenna systems for mobile satellite use, as reported in the JPL *MSAT-X Quarterly* and most recently in the *SATCOM Quarterly* [1]. Recently, JPL developed a Ka-band mobile vehicle antenna system that is much smaller and has higher gain than the L-band antennas. The new development is the ACTS Mobile Terminal (AMT) reflector antenna system. The AMT project at JPL will demonstrate mobile communications (voice, video and data) through ACTS soon after the satellite's launch in 1993. The reflector antenna system will be used for those demonstrations [2].

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The Satellite Communications (SATCOM) Program is managed by the Jet Propulsion Laboratory for the National Aeronautics and Space Administration. The goals of this Program are to develop advanced system concepts and technologies in the areas of mobile, micro and personal communications. A major thrust of the Program through the mid-1990s is the development of the mobile terminal to operate with NASA's Advanced Communications Technology Satellite.

The reflector antenna system was demonstrated at JPL EXPO II in June 1992; displayed outdoors, it was mounted on a computer-controlled platform that simulated vehicle movement. As the platform moved, the antenna tracked a 20-GHz beacon sent from the roof of a nearby building to simulate reception of the ACTS satellite downlink in a vehicular environment.

Development of Ka-band antenna technology is one of the key objectives of the AMT project. The benefits of moving to Ka-band include a substantial system size reduction and a much larger available bandwidth compared to lower frequency bands. However, reaping these benefits requires overcoming the disadvantages of higher RF component losses, significant rain attenuation [3], higher Doppler rates and the need for a more accurate satellite-tracking system to accommodate a narrower (higher gain) antenna beam. The AMT reflector antenna design overcomes these disadvantages. The following requirements for the reflector antenna system, which ensure a high level of performance for the overall AMT system, are met by the AMT reflector antenna system. The reflector antenna system shall:

- Be rugged enough to withstand the shock and vibration of the mobile vehicle environment.
- Complete a full azimuth search and acquire the satellite signal within 10 sec.
- Track the satellite by compensating for vehicle turn (yaw) rates up to 45 deg/sec and vehicle pitch and roll up to ±6 deg.

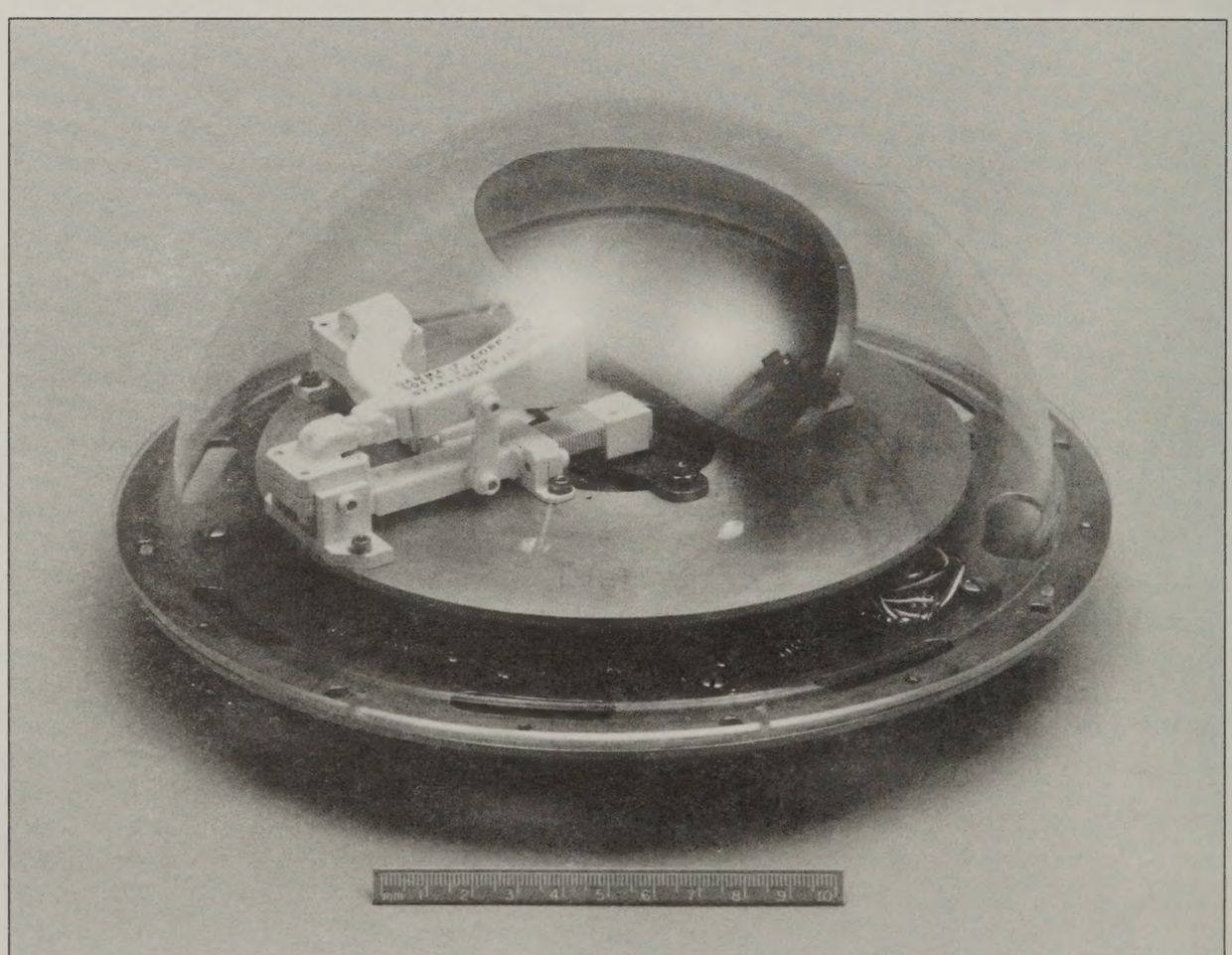
- Provide a minimum of 21 dBi of gain for transmission at 29.63 ±0.15 GHz, handle up to 10 W of transmit power and provide a minimum G/T of –8 dB/K over the receive band of 19.91 ±0.15 GHz.
- Have a relative cross-polarization level of no more than –17 dB and azimuth sidelobe and elevation backlobe levels of no more than –13 dB.

This article discusses the design of the AMT reflector antenna system and presents measurements of its performance. Photo A shows the AMT reflector antenna with a transparent mock radome; the actual radome has the same hemi-ellipsoidal shape but is opaque. The radome is 9 in. in diameter and has a peak height of 4 in. The reflector and the feedhorn assembly are clearly shown in the photograph. The antenna installs on the roof of the AMT vehicles and fits easily on either a van or a sedan. A coaxial connector at the center of the underside of the antenna is the sole RF connection that carries transmit and receive signals simultaneously between the antenna and the other AMT subsystems installed inside the vehicle. A second connector on the underside brings power to the antenna's motor. The computer that provides the antenna satellite tracking function mounts in a standard 19-in. rack drawer that is only 3.5 in. high.

Mechanical Design

Figure 1 is an exploded view of the antenna assembly. The reflector and feedhorn mount on a disk that attaches directly to the motor (without gears) to accomplish azimuth steering. Below the disk, an optical encoder assembly is mounted on the motor baseplate and monitors the disk angle to verify that the motor steers the antenna to the angle commanded by the antenna controller computer. All the antenna components are mounted directly on the motor or its baseplate, making the assembly simple, compact and rugged.

Photo A. AMT reflector antenna.



The motor is custom designed for durability and miniaturization. The motor design uses a matched pair of 2-in.-diameter angular-contact bearings with a 15-lb preload. This provides a very stiff mechanical system that supports the load of the antenna assembly (about 1.5 lb) under the dynamic stresses of the mobile vehicle environment while imposing less than 1 in.-ounce frictional torque. This two-phase pancake stepper motor design is only 0.5 in. high and 6 in. in diameter, with a 2-deg full-step angle and 40 in.-ounce of holding torque. The motor's rotor directly supports the load of the antenna. Therefore, no space is required for a gear box or pulley system. The motor assembly has a 1-in. hole in its center, like a donut, to accommodate the RF rotary joint; this configuration makes the rotary joint easy to replace in the field. All the antenna components mount directly to the motor or its baseplate; this high level of integration simplifies the mechanical system and enhances durability. The choice of materials and the motor design optimize the linearity of the motor. The use of an 8-bit microstepping motor drive produces nearly continuous angular resolution for precise antenna azimuth steering.

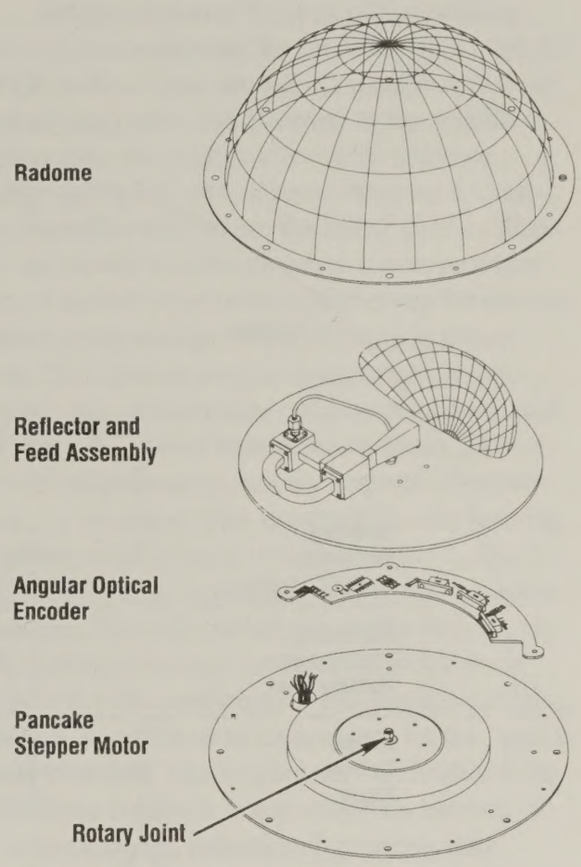


Figure 1. Reflector antenna exploded view.

RF Design

Figure 2 is a diagram of the antenna. The radome is a 0.15-in.-thick "A-sandwich" and imposes insertion losses of 0.2 dB at 20 GHz and 0.4 dB at 30 GHz. An electromagnetically transparent Vellox hydrophobic coating keeps water from wetting the radome surface and allows the AMT to maintain communications during light rain.

The antenna incorporates an offset reflector configuration to avoid feedhorn aperture blockage. The reflector is constrained to fit with the feedhorn under the radome and is relatively small — only about 4 by 10 wavelengths at 20 GHz. The basically elliptical reflector shape maximizes gain while providing a relatively wide elevation beamwidth to relax the need for satellite elevation tracking. The shape of the reflector is the intersection of a paraboloid and an elliptical cylinder, with the cylinder oriented so that the projection of the reflector surface is nearly a simple ellipse as viewed from both feedhorn and satellite directions. This orientation is important to ensure good illumination of the reflector by the feedhorn and a reasonably symmetrical antenna elevation pattern; it also contours the shape of the reflector to fit well under the radome. The reflector mounts on a manually adjustable fixture that sets the nominal elevation angle of the antenna beam to potentially allow operation with ACTS in any region of the continental United States (30–60-deg elevation). Only the reflector adjusts; the feedhorn remains fixed.

All the antenna's RF components are integrated into a single rigid assembly (except for the reflector and rotary joint) to reduce RF losses and increase mechanical integrity. Photo B shows the feedhorn, orthomode transducer and upper diplexer (the components above the rotary joint in Figure 2), all integrated into a single feedhorn assembly. The feedhorn assembly is a waveguide system that distributes both the 20- and 30-GHz signals from the rotary joint to the feedhorn. The single feedhorn is used for both frequency bands, with vertical polarization for the 20-GHz downlink and horizontal polarization for the 30-GHz uplink, which is required by ACTS. Immediately behind the feedhorn is the orthomode transducer, which combines the two

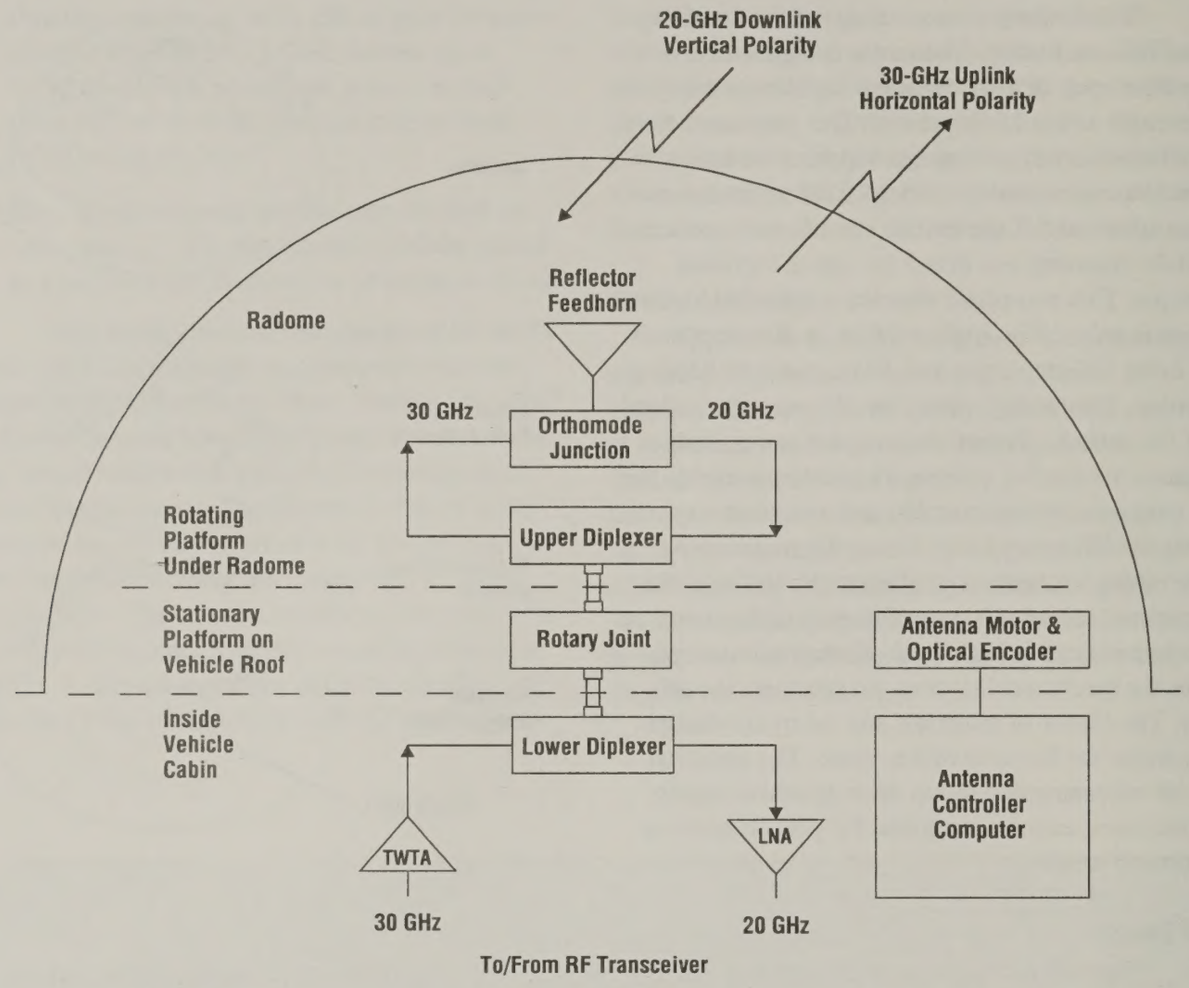


Figure 2.
Antenna system block diagram.

frequency bands from two different ports and channels them to the feedhorn after orienting them with the proper polarizations. The upper diplexer spatially separates the two frequency bands and distributes them to the respective ports of the orthomode transducer. The diplexer makes up most of the lower portion of the assembly. The feedhorn assembly also includes a coax-to-waveguide transition to adapt directly to the coaxial rotary joint connector, and a section of flexible waveguide that connects the coax transition to the rest of the waveguide structure and accommodates any misalignment of the rotary joint and motor axes as the motor turns. The RF loss through the feedhorn assembly is about 1.0 dB at 20 GHz and 1.5 dB at 30 GHz.

The rotary joint distributes the RF signals from the stationary motor base to the antenna components turned by the motor and provides the sole RF connection on the underside of the antenna. The rotary joint is a single-channel coaxial unit, and as such it is a relatively small unit that imposes a minimum of frictional torque — less than 5 in.-ounce. The rotary joint is only 0.5 in. in diameter and installs in the very center of the motor assembly, where it is easily field replaceable. The choice of such a small rotary joint is a major factor in achieving the overall reduction in antenna size. The RF loss through the rotary joint is about 0.5 dB.

A second (lower) diplexer, shown in Figure 2, attaches to the antenna's RF connector at the bottom of the rotary joint and interconnects the transmitter and receiver to the antenna. The lower diplexer is a separate unit but has the same design as that of the upper diplexer within the feedhorn assembly. A 20-GHz LNA with a 2.5-dB noise figure and 25 dB of gain helps satisfy the receive G/T requirement.

Satellite Tracking

A custom-designed turnkey microprocessor system — the antenna controller — tracks the satellite with the antenna as the vehicle moves about. Tracking the satellite requires only one-dimensional azimuth steering since the antenna elevation coverage is wide enough to accommodate typical vehicle pitch and roll variations within any single region of operation in the continental United States. The antenna controller steers the antenna in azimuth by controlling the motor in response to pointing information obtained from an inertial vehicle yaw sensor and a mechanical dithering pointing error signal. The satellite tracking system is a hybrid open-loop/closed-loop system very similar to that of the MSAT Yagi antenna described in a previous *SATCOM Quarterly* [1], but the AMT system is implemented quite differently and achieves substantially higher tracking accuracy. It uses an improved vehicle turn-rate sensor, mechanical dithering rather than monopulse feedback and a Motorola 68030 CPU real-time imbedded microprocessor system with a 25-MHz clock rate. Microprocessor software is written in C and assembly language.

Almost all that is required of the pointing system is to compensate for the turns (yaw) that the vehicle makes. Since the ACTS satellite will be in geostationary orbit, the direction to the satellite as viewed from the vehicle effectively does not change unless the vehicle turns. After an acquisition procedure determines the initial satellite direction, an inertial vehicle-yaw-rate sensor provides most of the information required to keep the antenna pointed at the satellite while the vehicle moves about. The antenna turns to compensate for the vehicle yaw variation measured by the sensor, and use of the full sensor bandwidth of about 300 Hz enables the antenna to quickly respond to vehicle turns. As the sensor bias slowly drifts, the tracking system eventually must compensate for it, detecting pointing error by using a mechanical dithering technique. Since the sensor bias drifts very slowly, the pointing error does not need to be corrected quickly; 0.1-Hz bandwidth of mechanical dithering feedback is sufficient to compensate for the inertial sensor bias drift. Minimizing the bandwidth of the closed-loop feedback is advantageous because of the accompanying reduction in pointing jitter

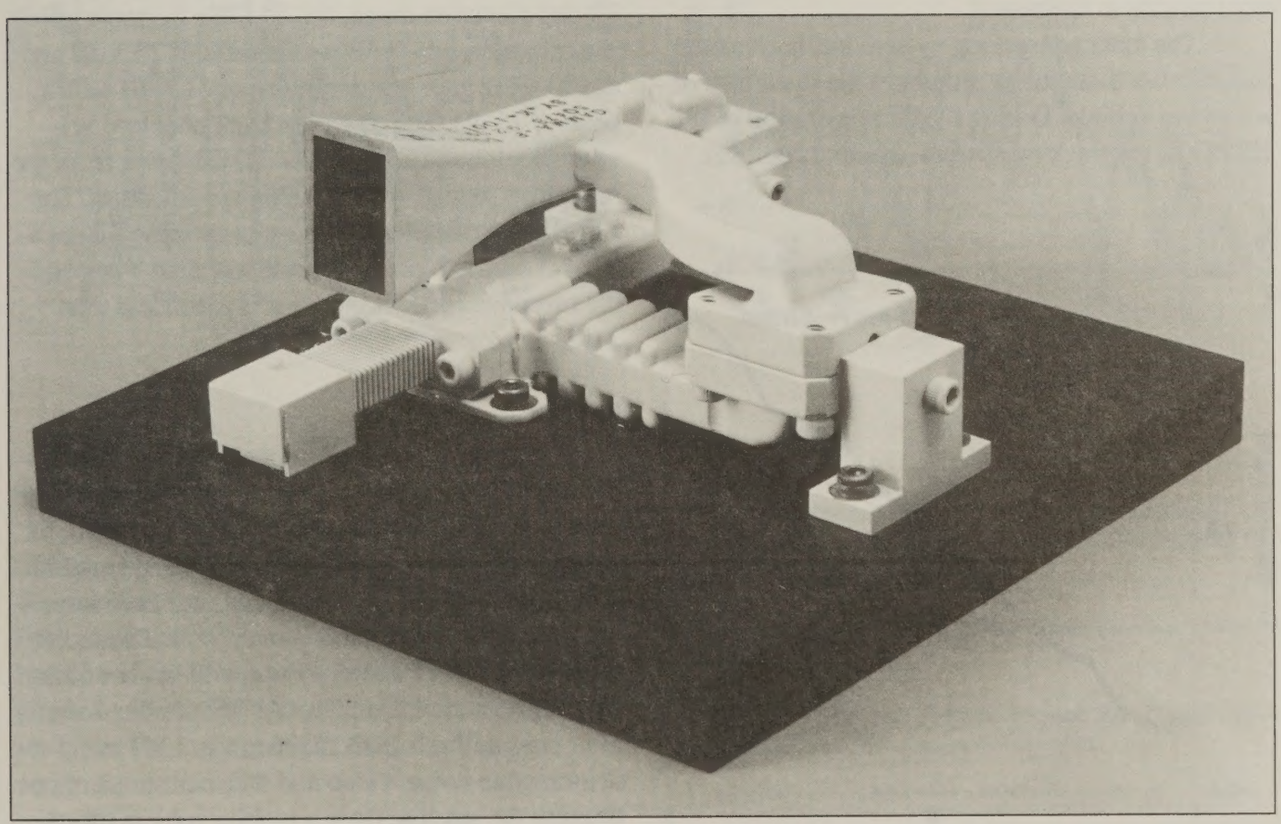


Photo B. Feedhorn assembly.

imposed by noise in the radio channel. The second-order closed-loop tracking system completely cancels steady-state rate sensor bias.

Mechanical dithering, the technique used to measure antenna azimuth pointing error, involves rocking the antenna back and forth sinusoidally (in azimuth angle) about 1 deg in each direction at a 2-Hz rate to determine if the antenna is pointed in the direction of the strongest signal. The satellite sends a special beacon for this purpose; the AMT's RF receiver detects the beacon through the antenna and provides the detected signal to the antenna controller computer. By correlating the received signal level reported by the RF receiver with the commanded dithering of the antenna angle, the antenna controller computer determines the sign and magnitude of any pointing error. Figure 3 shows the measured mechanical dithering pointing error detection function with a peak dither of 1 deg. At large error angles, the function reveals a small nonlinearity in the motor.

The antenna tracking system has been tested in a manner that closely simulates the dynamics of a moving vehicle. During the demonstration at JPL EXPO II, the tracking system operated continuously eight hours per day for two days in a hot outdoor summer environment. It compensated for turn rates up to about 60 deg/sec — much higher than the 45 deg/sec required. The rms pointing error while tracking is only a small fraction of a degree, and the maximum instantaneous pointing error is only about 2 deg during turns. The worst-case pointing jitter as a function of SNR is no more than about 0.5 deg. The tracking system is able to complete a full azimuth scan and acquire the signal in about 5 sec.

After an acquisition procedure determines the initial satellite direction, an inertial vehicle-yaw-rate sensor provides most of the information required to keep the antenna pointed at the satellite while the vehicle moves about.

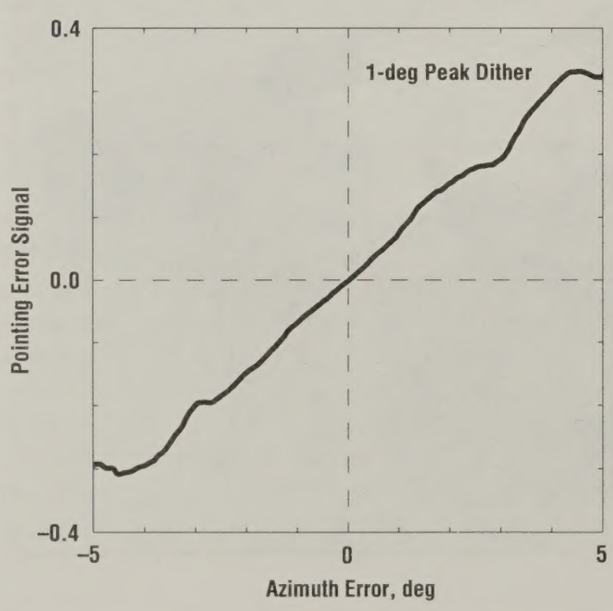


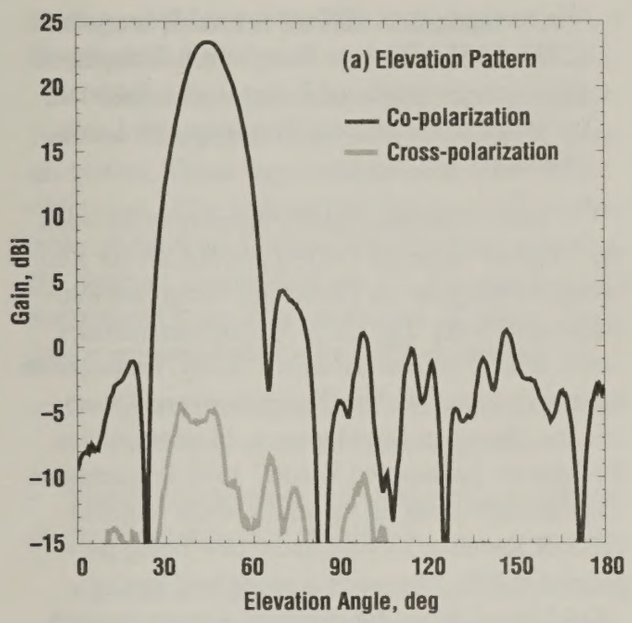
Figure 3. Mechanical dithering pointing error detection.

Antenna Patterns

Figures 4(a)–(b) and 5(a)–(b) present the elevation and azimuth (co- and cross-polarization) 20- and 30-GHz patterns of the AMT reflector antenna as measured at the JPL Mesa Antenna Range facility. The patterns show the 12-deg elevation range coverage centered at 46 deg for the Southern California ACTS experiments. Over the required 12-deg elevation range, the 20-GHz isotropic gain is a minimum of 20 dB with a peak of 23.5 dB and the 30-GHz gain is a minimum of 21.3 dB with a peak of 25 dB. The elevation backlobes and azimuth sidelobes are more than 20 dB down from the main lobe, which is well within specification. The −17-dB specification for cross-polarization is satisfied for azimuth pointing error less than 3 deg and the rms antenna tracking error is much less than 3 deg.

Conclusion

JPL has successfully developed a mobile vehicle reflector antenna system for the Ka-band ACTS Mobile Terminal. The system is rugged, for operation in the mobile environment, and small in size. Initial tests show that the antenna and its satellite tracking system perform very well. The mobile vehicle reflector antenna system will be part of the first experimental use of the ACTS satellite soon after the satellite's launch, when the AMT will demonstrate voice, video and data communications through the satellite from a mobile vehicle traveling roads in the Southern California area.



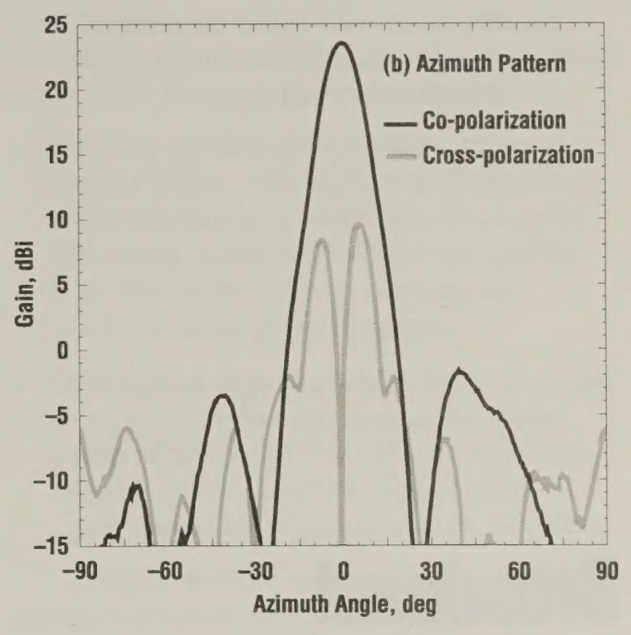
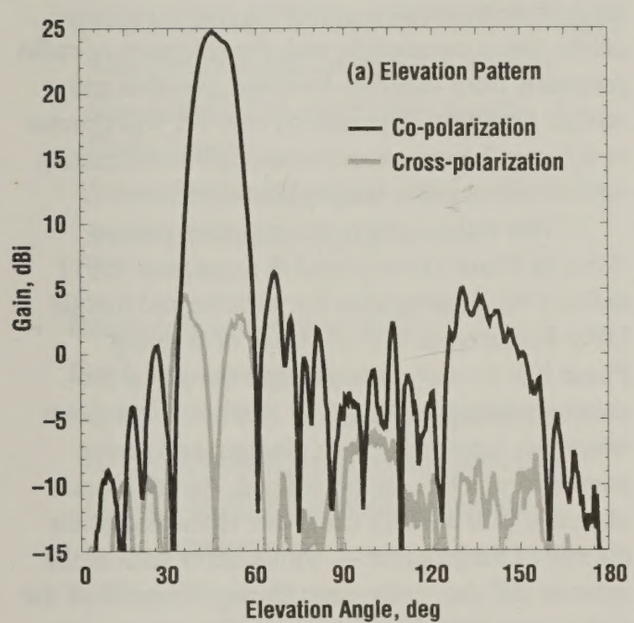


Figure 4. 20-GHz elevation and azimuth patterns.



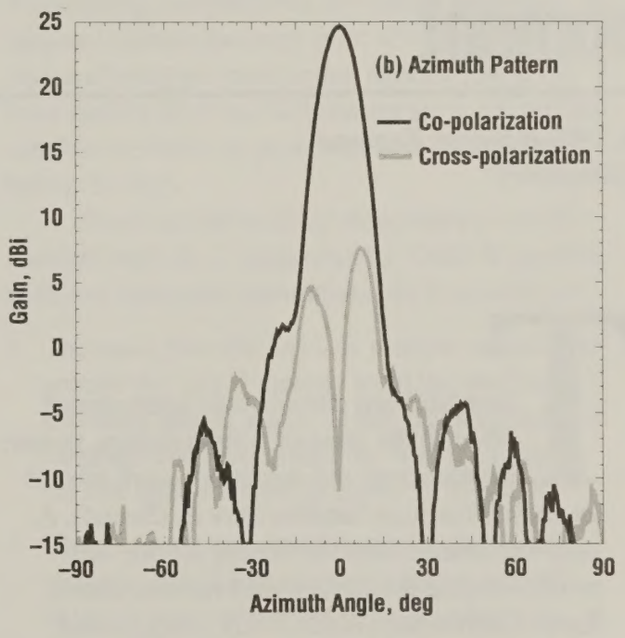


Figure 5. 30-GHz elevation and azimuth patterns.

Acknowledgments

Many diligent people made the development of this antenna system a success, including Cosme Chavez and Bob Thomas; Lee Sword, Doug Packard, Richard Blomquist, Bill White, John Kievit and Don Bickler of the JPL mechanical engineering staff; Ken Lau of the JPL control systems staff, and the management of the AMT project.

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Direct Broadcast Satellite–Radio Receiver Development

Nasser Golshan, DBS–R System Engineer
Jet Propulsion Laboratory

There has been considerable international effort in the areas of system studies, system development and regulatory work toward an audio Broadcast Satellite Service (Sound). A very important milestone for this service was reached during the 1992 World Administrative Radio Conference (WARC–92), when L- and S-band frequencies were allocated [1]. (*See also the article on WARC satellite broadcasting allocations in SATCOM Quarterly No. 6, July 1992. –Ed.*) BSS (Sound) and complementary terrestrial broadcasting services were received as follows:

- A primary worldwide allocation of 40 MHz of L-band spectrum (1452–1492 MHz), with a number of countries, including the United States, restricting this service at this frequency via footnotes.
- Via footnote, 50 MHz of S-band spectrum (2310–2360 MHz) for the United States and India.
- Via footnote, 120 MHz of S-band spectrum (2535–2655 MHz) for Bangladesh, Belarus, China, the Republic of Korea, India, Pakistan, the Russian Federation, Singapore, Sri Lanka, Thailand and Ukraine.

There is an interagency agreement between the Voice of America (VOA) and NASA for a coordinated program on Direct Broadcast Satellite–Radio (DBS–R). The DBS–R Program includes seven tasks: Systems Tradeoffs Study, Propagation Measurements, Satellite Experiment and Demonstration, Receiver Development, Market Studies, Regulatory Studies and WARC 1992 Preparations. This article reports on the status of the ongoing DBS–R Receiver Development task being performed at JPL. The work is sponsored by the VOA/United States Information Agency through an agreement with NASA.

The objective of the task is to develop, build, test and demonstrate a prototype digital radio receiver that is compatible with the reception of radio programs from satellites for fixed, portable and mobile reception. The desired receiver will operate at different bit rates to accommodate broadcasting with different audio-quality/cost objectives.

This task is structured into three phases. Work in Phase I (completed in fiscal year 1991) defined the requirements for portable and mobile DBS–R receivers. The objective of ongoing Phase II is to analyze and design the signal processing portions of a DBS–R receiver to the point where the functional block diagram and performance parameters can be defined. An additional objective is to identify candidate technologies for the rest of the receiver — components such as the antenna and the synthesizer. During Phase III of the task, a prototype digital radio receiver that is compatible with the reception of radio programs from satellites will be built, tested and demonstrated.

Tradeoffs have been made to meet the requirements for portable indoor reception while maintaining signal compatibility with proposed satellite/terrestrial concepts.

Findings of Phase I of the DBS–R Receiver Development Task

Receiver requirements have been identified from the viewpoints of both the user and the overall system. These requirements are driven by the objectives of the task and the findings of the other tasks of the NASA/VOA DBS–R effort, namely the Systems Tradeoffs Study [2], Propagation Measurements [3] and Market Studies [4] tasks. The major requirements for the DBS–R receiver are:

- Design compatible with low-cost production of the radio receiver as a consumer product.
- Mobile and portable (including indoor table-top portable) reception of DBS–R.
- Variable bit rate decoding to meet the following different audio-quality/broadcast-cost requirements based on the findings of the DBS–R Systems Tradeoffs Study (with adjustments to reflect very recent advances in the technology):

  AM-quality digital audio at 16–32 kbps

  Monophonic FM-quality digital audio at 48–64 kbps

  Stereo FM-quality digital audio at 64–96 kbps

  Stereo CD-quality digital audio at 128–196 kbps
- Receiver figure of merit (G/T):

  For L-band operation

  G/T = –19 dB/K for mobile applications

  G/T = –19 dB/K for portable applications

  G/T = –16 dB/K for table-top portable applications

  For S-band operation

  G/T = –19 dB/K for mobile applications

  G/T = –19 dB/K for portable applications

  G/T = –12 dB/K for table-top portable applications

Tradeoffs have been made on a number of signal design and diversity techniques to meet the requirements for portable indoor reception of DBS–R transmissions while maintaining signal compatibility with proposed hybrid satellite/terrestrial concepts, particularly for urban mobile reception. The diversity tradeoff for indoor portable reception is significantly influenced by the findings of the DBS–R propagation measurements:

- When the signal level is displayed jointly as a function of frequency and spatial displacement, amplitude troughs of several dB are observed. The widths of amplitude troughs are typically 5–30 MHz in the frequency domain and 10–30 cm in the spatial dimension.
- Close-spaced antenna diversity has been chosen over frequency diversity because the spatial widths of indoor signal troughs are short (typically 10–30 cm) while the spectral widths of signal troughs are relatively wide (5–30 MHz).

Finally, an FDM signal structure with QPSK modulation and forward error correction (FEC) with time interleaving has been chosen as the optimum structure for portable DBS–R reception while maintaining compatibility for mobile reception. An optional spread-spectrum pilot will be used to measure and mitigate intersymbol interference (to be used mainly if terrestrial boosters are used or if the satellite elevation angle is very low — typically below 10 deg).

Based on the receiver requirements and the tradeoff analysis, a basic portable DBS–R receiver with two enhancement options has been selected:

- The basic portable DBS–R receiver intended to receive the signal directly from the satellite at elevation angles above 10 deg (typical) is based on phase-coherent detection. A block diagram for this basic receiver is shown in Figure 1.
- Close-spaced antenna diversity is an optional enhancement for the basic portable receiver. A block diagram for this option is shown in Figure 2. The dotted lines show two possible positions where the signals from the two antennas can be combined.
- An optional circuit will process a spread-spectrum pilot to measure and mitigate intersymbol interference. A block diagram for this option is shown in Figure 3.

Plans for Phase II

The technical activities planned for the second phase of the DBS–R Receiver Development task are organized into three subtasks: Analysis, Simulation and Receiver Component Definition.

Figure 1.
Basic receiver.

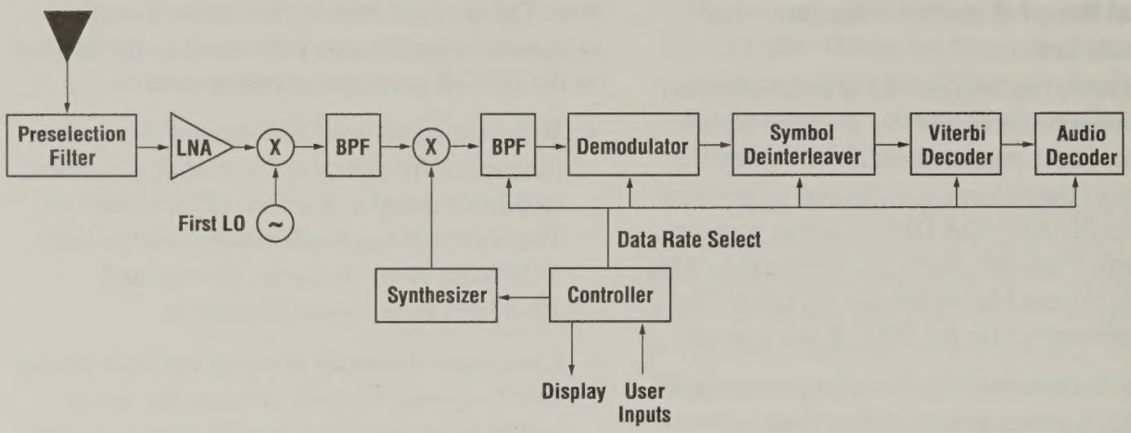


Figure 2.
Antenna diversity.
Shaded areas show optional enhancements.

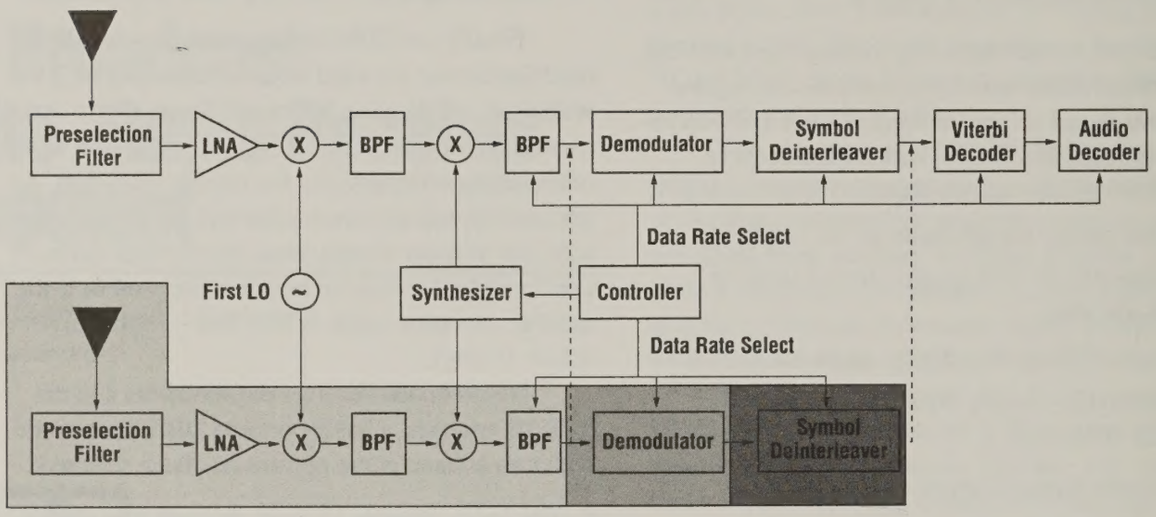
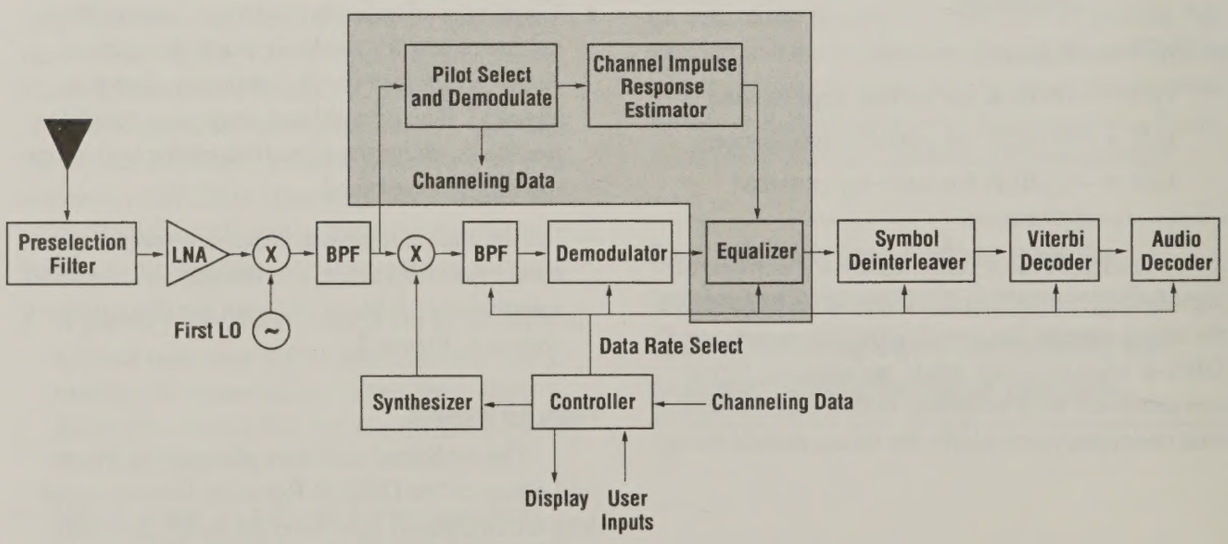


Figure 3.
Channel equalization.
Shaded areas show optional enhancements.



The performance of the basic receiver and the proposed options are being evaluated by analysis and simulation assuming QPSK modulation with FEC using rate 1/2 and 1/3 constraint 7 convolutional codes. Time interleaving is included to mitigate intermittent signal interruptions in mobile channels. Simulation and analysis are being performed with center frequency and spectrum width as variables corresponding to spectrum allocated at WARC–92.

The approximate BER performance of the proposed basic receiver has been determined by analysis both for portable and mobile reception using appropriate simplifying assumptions to make the analysis feasible. The simplifying assumptions include a Gaussian channel for portable reception and an on/off shadowing channel for mobile reception.

An effort is underway to determine the performance of the proposed receiver using realistic L- and S-band channel models including multipath, signal blockage and scintillation. The outcome of the simulation will define the functional block diagram and performance parameters for the basic portable and mobile receivers and the optional features of antenna diversity and channel equalization. Finally, candidate technologies for the rest of the receiver — such as antenna, low-noise amplifier, synthesizer and audio decoder — will be identified.

Conclusion

The initial phase of the task has identified receiver requirements for portable and mobile reception of DBS–R. Analysis and simulation are underway to validate and refine the proposed receiver designs. The third phase of the project will address building, testing and demonstrating a prototype receiver.

Acknowledgments

At JPL, significant contributions to this task have been made by David Bell, Marvin Simon and Arvydas Vaisnys. James Hollansworth (NASA DBS–R Program Manager at Lewis Research Center) and H. Donald Messer (DBS–R Program Manager at Voice of America) provided program management.

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Communications CCDS Established at FAU

William E. Glenn, Director
Space Communications Technology Center
Florida Atlantic University

The Space Communications Technology Center (SCTC) at Florida Atlantic University (FAU) is one of NASA's newly established Centers for the Commercial Development of Space (CCDS). The SCTC is devoted to developing the technologies required for the digital transmission of video, audio and other data by satellite.

Video Technology Changes

Video comprises most of the information currently being transmitted by communications satellites. The television industry is experiencing dramatic changes in the technology it uses; for example, video distribution by terrestrial broadcast is rapidly decreasing. Cable television — which receives most of its program material by satellite to cable "headends" — and direct broadcast satellite now represent most of the distribution of video.

Broadcast of video by analog modulation on an FM subcarrier has been the primary communication satellite technique. However, the television industry is rapidly converting to all-digital signals for recording and distribution within the studio, and digital distribution in compressed form is being seriously considered for all distribution media.

The conversion to digital distribution has been accelerated by efforts on the part of industry to develop a high-definition television (HDTV) terrestrial broadcast standard that can broadcast HDTV within the bandwidth of a single 525-line (6-MHz bandwidth) analog television channel. All three leading proponents for the standard are using digital transmission of compressed video.

There are significant advantages to digital recording and distribution compared with analog techniques. Digital transmission provides a completely "transparent" link from the camera to the display. Many generations of postproduction editing followed by many subsequent distribution links can be performed without any increase in noise, reduction in resolution or introduction of artifacts such as multipath "ghosts."

Video Compression Technology

Compression technology has been able to preserve the advantages of digital distribution and transmit an image that would normally take over five times that bandwidth using analog transmission. This factor of five can be used either to transmit HDTV within a single television channel or transmit five 525-line images in that channel. As a result of these advances, the Federal Communications Commission plans to approve an HDTV standard for terrestrial broadcast in 1993. Cable companies are seriously considering using digital distribution within the cable system as well as digital distribution to cable headends by satellite. The companies are also considering digital transmission directly to customers' homes by direct broadcast satellite. In addition, one company has demonstrated a compressed digital HDTV recording on a standard 8-mm camcorder cassette with a playing time of two hours.

NASA has been a leader in the conversion of video distribution from analog techniques to the use of compressed digital signals. Space Station Freedom has been designed to transmit compressed video to Earth digitally using NASA's extant

Tracking and Data Relay Satellite System. For almost a decade, the Television Development Division of NASA's Office of Public Affairs has sponsored a program, for which I am the principal investigator, to develop digital compression techniques for 525-line television and HDTV for this application.

Compression technology works by leaving out information. Only two classifications of information can be left out without visible loss: the first involves a study of scene statistics and the second requires a complete understanding of visual perception.

Digital transmission of compressed video is a very complex problem. There is a strong interaction between RF propagation problems (rain fades, noise, multipath, etc.), error-correction codes and the type of compression used. The compression algorithm and the error-correction techniques used depend on the RF spectrum, type of modulation and whether GEO or non-GEO satellites are employed. Compression algorithms that have high compression ratios may be very intolerant of drop-outs — the loss of a single bit can devastate the image. Systems with less compression can tolerate considerable errors and can be made to "fail gracefully" as drop-out rates increase. As a result, the choice of the compression algorithm and the error-correction technique depends on the transmission medium.

SCTC Research

The SCTC program comprises three areas of research whose personnel must work very closely together to develop viable digital satellite communication systems: RF propagation measurements and modulation techniques; error correction and digital signal handling, and compression technology.

In the field of RF propagation measurements and modulation techniques, measurements will be made using the ACTS satellite for Ka-band transmission from a geostationary orbit. One of seven NASA-sponsored propagation terminals will be set up at the University of South Florida. Ancillary experiments utilizing a second, receive-only terminal will be developed to compare beacon and in-band signal strengths, as well as to initiate a characterization study of the ACTS wide-bandwidth channel.

The FAU CCDS/SCTC, in conjunction with its industrial partner, Motorola, is sponsoring a LEO experiment for inclusion on the COMET–01 service module payload mission. The experimental payload will consist of two coupled L- and S-band transponders operating in "bent pipe" modes. The L-band transponder will be bidirectional and centered at 1618 MHz; the S-band uplink will be centered at 2040 MHz and the downlink at 2491 MHz. Instantaneous bandwidths of up to 2 MHz can be accommodated. The aim of this experiment is to explore generic digital transmission and propagation issues that will aid in the development of commercial LEO communication systems. Experiments will study the ability to acquire data while tracking a rapidly moving satellite, effects of low elevation angle multipath, modulation tradeoffs, error-correcting codes and fading at L- and S-bands.

The research in error correction and digital signal handling is aimed at determining acceptable drop-out levels and delay times. The techniques used depend on the measured deficiencies of the RF link and the allowable drop-out level of the compression algorithm that is employed.

Compression technology, the third area of research, works by leaving out information. Only two classifications of information can be left out without visible loss: information one can predict about the scene and information the viewer cannot see. The first category involves a study of scene statistics and the second requires a complete understanding of visual perception. Table 1, from [1], summarizes the visual perception phenomena that can be used to leave out information that cannot be seen. Further compression can be achieved based on scene predictability. The combination of these factors results in a dramatic reduction in bit rate. About 99% of the bits in an 8-bit encoded RGB moving image can be left out without a noticeable difference in the image.

As the SCTC program progresses and real-time hardware is completed, experiments are planned in which compressed digital HDTV video will be transmitted by satellite using appropriate

Table 1. Compression techniques used to leave out unseen information.

Compression technique (based on visual perception)	Estimated compression ratio
Use progressive scan with 3-D sub-band coding of luminance rather than interlaced scan	1.0
Take advantage of transient masking in luminance and color in 3-D sub-band coding	1.4
Do not encode high-amplitude, high spatial frequencies due to low modulation transfer function of camera	1.3
Take advantage of low-contrast sensitivity of vision in high spatial frequencies to increase truncation thresholds and reduce number of bits of gray scale	1.7
Use lower resolution isoluminant color signals for color at a lower temporal frequency	2.7
Take advantage of the oblique effect (diagonal sampling or reduced diagonal coefficients for discrete cosine transform)	1.4
Represent images by discrete spatial frequencies and discrete orientations	2.0
Represent motion by discrete vectors in velocity and direction applied to temporally sampled images	2.0
Use optimum pre- and postspatial filtering	1.2
Use optimum pre- and post-temporal filtering	?
Take advantage of pattern on pattern masking in luminance to raise truncation levels in transform coefficients	?
Take advantage of color on luminance pattern masking to raise truncation levels in transform coefficients	?
Total	~>56

error-correcting codes. These experiments, along with experiments transmitting other digitally encoded information, will be performed with ACTS and other communication satellite experiments on subsequent launches.

Additional Information

For further information on the SCTC programs, telephone:

- Dr. William E. Glenn, CCDS Director and Associate Director for Video Compression Technology, (407) 367-3411.
- Dr. Henry Helmken, Associate Director for RF Propagation Measurements and Modulation Techniques, (407) 367-3452.
- Dr. Richard Newman-Wolfe, Associate Director for Digital Signal Handling, (904) 392-1488.

References

[1] W. E. Glenn, "Digital Image Compression Based on Visual Perception and Scene Properties," presented at the 133rd SMPTE Technical Conference, October 26–29, 1991, Los Angeles, California, preprint No. 133-31.

New JPL SATCOM Personnel

DR. ROBERT K. KWAN recently joined the Jet Propulsion Laboratory as the Telecommunications Science and Engineering Division's Satellite Communications Chief Engineer. Dr. Kwan has 30 years of experience in satellite communications research and development, working with Bell Northern Research, Telesat Canada and COMSAT. Immediately before coming to JPL, Dr. Kwan served as the Program Manager and Senior Scientist at Space Systems/LORAL, where he was responsible for the development of advanced SATCOM concepts for commercial applications. At JPL, Dr. Kwan will provide technical leadership for advanced satellite communications concepts, interface with the satellite communications industry and identify satellite communications technology needs that may be effectively met by the JPL SATCOM Program. Dr. Kwan is also the Technical Co-Chair for the Third International Mobile Satellite Conference (IMSC '93), which will be held next June in Pasadena, California.

JPL SATCOM Program Contacts

Area	Contact	Mail Stop	Phone*
SATCOM Program Manager	Dr. A. L. Riley	238-540	354-0401
Publications	Randy Cassingham	601-237	354-0455
Propagation	Dr. Faramaz Davarian	161-228	354-4820
Optical Communications	Dr. James R. Lesh	161-135	354-2766
Advanced Studies	Dr. Polly Estabrook	238-420	393-9048
ACTS Mobile Terminal	Thomas Jedrey	238-420	354-5187
Technology Transfer	Dr. Robert Kwan	238-420	354-2349
ACTS Mobile Terminal Experiments	Brian Abbe	238-420	354-3887

**Area code 818.*

IMSC '93 PLANNED FOR JUNE

The Third International Mobile Satellite Conference (IMSC '93) and Exhibition is planned for June 16–18, 1993, in Pasadena, California. Cosponsored by NASA/JPL and the Canadian Department of Communications/Communications Research Centre, IMSC '93 will serve as a forum to review and demonstrate the design, development and applications of mobile satellite systems and associated regulatory and policy aspects of this technology. In particular, the conference will focus on the growing personal satellite communications industry.

The Call for Papers was mailed in September. For additional information, or more copies of the Call for Papers, contact:

IMSC '93 Organizing Committee
Jet Propulsion Laboratory, MS 601-237
4800 Oak Grove Drive
Pasadena, California 91109-8099
U.S.A.

Tel: 818-354-1260
Fax: 818-393-9876

NASA
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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